Health Consultation

Cadet Manufacturing
Vancouver, Clark County, Washington

January 29, 2002
Revised contact information September 19, 2003

Prepared by
The Washington State Department of Health
under a Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

Foreword

The Washington State Department of Health (DOH) has prepared this health consultation in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the U.S. Department of Health and Human Services and is the principal federal public health agency responsible for health issues related to hazardous waste. This health consultation was prepared in accordance with methodologies and guidelines developed by ATSDR.

The purpose of this consultation is to identify and prevent harmful human health effects resulting from exposure to hazardous substances in the environment. Health consultations allow DOH to respond quickly to a request from concerned residents for health information on hazardous substances. It provides advice on specific public health issues. DOH evaluates sampling data collected from a hazardous waste site or industrial site, determines whether exposures have occurred or could occur, reports any potential harmful effects, and recommends actions to protect public health.

For additional information or questions regarding DOH, ATSDR or the contents of this health consultation, please call:

Washington State Department of Health
Office of Environmental Health Assessments
PO Box 47846
Olympia, WA 98504-7846
Phone: (360) 236-3370
Fax: (360) 236-3383
Toll free: 1-877-485-7316

Glossary

Acute	Occurring over a short period of time. An acute exposure is one which lasts for less than 2 weeks.
Agency for Toxic Substances and Disease Registry (ATSDR)	The principal federal public health agency involved with hazardous waste issues, responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life. ATSDR is part of the U.S. Department of Health and Human Services.
Aquifer	An underground formation composed of materials such as sand, soil, or gravel that can store and/or supply groundwater to wells and springs.
Cancer Risk Evaluation Guide (CREG)	The concentration of a chemical in air, soil or water that is expected to cause no more than one excess cancer in a million persons exposed over a lifetime. The CREG is a *comparison value* used to select contaminants of potential health concern and is based on the *cancer slope factor* (CSF).
Cancer Slope Factor	A number assigned to a cancer causing chemical that is used to estimate it's ability to cause cancer in humans.
Carcinogen	Any substance that can cause or contribute to the production of cancer.
Chronic	A long period of time. A chronic exposure is one which lasts for a year or longer.
Comparison value	A concentration of a chemical in soil, air or water that, if exceeded, requires further evaluation as a contaminant of potential health concern. The terms comparison value and screening level are often used synonymously.

Contaminant	Any chemical that exists in the environment or living organisms that is not normally found there.
Dose	A dose is the amount of a substance that gets into the body through ingestion, skin absorption or inhalation. It is calculated per kilogram of body weight per day.
Environmental Media Evaluation Guide (EMEG)	A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The EMEG is a *comparison value* used to select contaminants of potential health concern and is based on ATSDR's *minimal risk level* (MRL).
Exposure	Contact with a chemical by swallowing, by breathing, or by direct contact (such as through the skin or eyes). Exposure may be short-term (acute) or long-term (chronic).
Groundwater	Water found underground that fills pores between materials such as sand, soil, or gravel. In aquifers, groundwater often occurs in quantities where it can be used for drinking water, irrigation, and other purposes.
Hazardous substance	Any material that poses a threat to public health and/or the environment. Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive.
Indeterminate public health hazard	Sites for which no conclusions about public health hazard can be made because data are lacking.

Ingestion rate	The amount of an environmental medium which could be ingested typically on a daily basis. Units for IR are usually liter/day for water, and mg/day for soil.
Lowest Observed Adverse Effect Level (LOAEL)	LOAELs have been classified into "less serious" or "serious" effects. In dose-response experiments, the lowest exposure level at which there are statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and its appropriate control.
Maximum Contaminant Level (MCL)	A drinking water regulation established by the federal Safe Drinking Water Act. It is the maximum permissible concentration of a contaminant in water that is delivered to the free flowing outlet of the ultimate user of a public water system. MCLs are enforceable standards.
Media	Soil, water, air, plants, animals, or any other part of the environment that can contain contaminants.
Minimal Risk Level (MRL)	An amount of chemical that gets into the body (i.e., dose) below which adverse health effects are not expected. MRLs are derived by ATSDR for acute, intermediate, and chronic duration exposures by the inhalation and oral routes.
Monitoring wells	Resource protection wells installed at locations on or off a hazardous waste site so groundwater can be sampled at selected depths and studied to determine the movement of groundwater and the amount, distribution, and type of contaminant.
No apparent public health hazard	Sites where human exposure to contaminated media is occurring or has occurred in the past, but the exposure is below a level of health hazard.

Oral Reference Dose (RfD)	An amount of chemical ingested into the body (i.e., dose) below which health effects are not expected. RfDs are published by the U.S. Environmental Protection Agency (EPA).
Parts per billion (ppb)/Parts per million (ppm)	Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.
Plume	An area of contaminants in a specific media such as groundwater.
U.S. Environmental Protection Agency (EPA)	Established in 1970 to bring together parts of various government agencies involved with the control of pollution.
Volatile organic compound (VOC)	An organic (carbon-containing) compound that evaporates (volatilizes) easily at room temperature. A significant number of the VOCs are commonly used as solvents.

Background and Statement of Issues

The Washington State Department of Health (DOH) prepared this health consultation at the request of the Washington State Department of Ecology (Ecology) to evaluate potential human health risks associated with the release of toxic chemicals at the *Cadet Manufacturing Company* (Cadet). DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Cadet is located at 2500 W. Fourth Plain Boulevard in a mixed industrial, commercial, and residential area of Vancouver, Clark County, Washington (Appendix A, Figure 1).[1] A residential area known as the Fruit Valley Neighborhood (FVN) borders Cadet to the east. To the south is Fourth Plain Boulevard, which is bordered on the south by the Port of Vancouver property. To the immediate north and west is a vacant L-shaped industrial parcel, and further to the north is more of the FVN followed by rural property (Figure 2). This site has been used for manufacturing electric home heaters since 1964. Part of that process included degreasing metal parts with chlorinated solvents followed by spray painting. Cadet discontinued the use of this cleaning process in 1976.

Swan Manufacturing (Swan) produced electric home heaters at the Cadet site from 1964 until 1972. Prior to 1964, Swan operated at another site, the former Port of Vancouver Building 2220, located approximately a block south of Cadet (Figure 1). Both companies used vapor degreasing pits and waterfall structures to collect over-spray. Cadet continued this practice until 1987. Wastewater from the waterfall structures at the Cadet facility drained directly into the sanitary sewer. Two breaks in the sewer beneath the east side of Cadet property were discovered and repaired in the early and mid 1990s.[1] No remediation has occurred at the Cadet site.[2]

In January 2000, Cadet and Ecology entered into a legal agreement (Agreed Order) that requires Cadet to investigate the nature and extent of chlorinated solvent contamination in soil and groundwater at the site.[1] Chlorinated solvents consist of volatile organic compounds (VOCs) such as trichloroethylene (TCE) and tetrachloroethylene (PCE). Ecology has been concerned about VOCs moving from the Cadet facility to residential wells, public wells operated by the Port of Vancouver, and industrial wells operated by Great Western Malting where VOCs have been detected. The relationship between the Cadet groundwater contamination and the contamination discovered in the residential, public and industrial wells has not been established. However, it will be investigated by Ecology in the near future along with other nearby facilities where VOCs releases have occurred. Migration of VOCs from soil and groundwater into indoor air of residential homes and the Cadet facility is also an exposure pathway of concern.

Numerous samples of soil, drinking water, groundwater, indoor air, and soil gas at Cadet and surrounding areas have been analyzed for VOCs. TCE, PCE, and 1,1,1-trichloroethane (TCA) were consistently detected in soil gas in the vicinity of Cadet and the FVN, (area north of Fourth Plain Boulevard, south of 31st Street and west of W. Fruit Valley Road).[3] The distribution patterns suggest that the source of VOC contamination in the soil vapor is the underlying contaminated groundwater.

Soil

The highest concentrations of TCE and PCE in soil on the Cadet property are 14 and 1.7 parts per million (ppm), respectively. These concentrations are below the most conservative ATSDR health comparison values of 60 ppm for TCE and 10 ppm for PCE. Health comparison values are compared with concentrations of contaminants in air, soil or water. Concentrations below health comparison values are not considered to be a health concern while those that exceed health comparison values are considered further in the discussion section.

Groundwater

The direction of groundwater flow in the area of the Cadet facility varies depending on the time of year and is influenced by the level of the Columbia River. Groundwater data collected since late 1999 indicates that the depth of the shallow groundwater table ranges from 11 to 37 feet below ground surface (bgs) in the vicinity of the Cadet facility. Groundwater fluctuates approximately 9 feet throughout the year. The lowest groundwater elevation is approximately 2.5 feet above mean sea level (msl); the highest elevation approximately 11.5 feet.[4] Shallow groundwater levels and water quality data generally indicate an easterly groundwater flow direction from the Cadet facility.

Groundwater on the Cadet property and beneath the FVN is contaminated with TCE, PCE, TCA, cis-1,2-dichloroethene (cis-1,2-DCE), and 1,1-dichloroethene (1,1-DCE). The highest concentrations of these compounds were found near the Cadet facility (Table B1). The source of contamination is believed to be historic releases from the sewer lines at the Cadet facility. The highest groundwater concentrations of TCE and PCE were found beneath the east side of the Cadet building, near the sanitary sewer line (Figure 2). TCE and PCE were detected in June 2000 at 78,000 parts per billion (ppb) (station C-13) and in November 2000 at 70,000 ppb (station C-9), respectively.[4,5]

Although the relationship between the Cadet groundwater contamination and the residential, public, and industrial wells has not been established, DOH evaluated groundwater data obtained from these private wells to determine whether the detected contaminants pose a health threat.

Concentrations of VOCs in *drinking water* from the farm residence and rental house are provided in Table B2. The farm residence is located approximately 3,000 feet northwest of Cadet, and the rental house is located approximately 3,000 feet north-northwest of Cadet (Figure 1). The drinking water wells serving these homes were found to be contaminated with TCE and PCE at maximum concentrations of 4.37 and 1.13 ppb, respectively. Both of these residences will be connected to the City of Vancouver municipal water supply by December 2001.

Ecology and the Southwest Washington Health District (SWWHD) have been concerned with potential contamination of three Port of Vancouver drinking water wells located 4,420 feet south of Cadet on the east side of the Great Western Malting grain elevators. These wells do not serve residences but are used for drinking water at approximately 40 percent of the facilities in the Port of Vancouver industrial area. The use of these wells for drinking water will be phased out over the next two years and water services will be replaced with City of Vancouver municipal water. Quarterly sampling of the Port wells has shown one detection of TCE (6.7 ppb in March 1996) above the state drinking water standard of 5 ppb, known as the maximum contaminant level (MCL). TCE has not been detected in the Port wells since March 1998.

Great Western Malting uses four wells that draw up to 10 million gallons per day for processing barley from four different groundwater wells.[2] These wells are not used for drinking water. Well #1 is no longer used. Wells 2 and 3, located on the south side of the plant are used for approximately 30 percent of the processing. A maximum concentration of 1.1 ppb TCE was found in wells 1 and 2, however, the TCE level is below the MCL. Wells 4 and 5 are located on the north side of the plant and have shown a maximum concentration of 35 ppb prior to March 2001. However, on March 16, 2001, air stripping towers were installed to remove TCE from wells 4 and 5. TCE has not been detected in these wells after air stripping treatment.

Indoor Air

VOCs in groundwater can migrate through the soil column and infiltrate into indoor air. Cadet conducted indoor air monitoring at its facility in March 2001. TCE, PCE, 1,4 dichlorobenzene, and m,p-xylene were detected (Table B3).

No indoor air monitoring has been conducted in the FVN. Cadet, however, collected soil gas samples from 3 to 4 feet below ground surface (bgs) in open areas within the FVN and its facility using a push probe technique to estimate VOCs. Analysis of soil gas showed elevated levels of VOCs at both Cadet and the FVN. Soil gas VOC levels measured at the Cadet facility were much higher (1,800,000 ug/m^3 for TCE and 220,000 ug/m^3 for PCE) than those in the FVN. Maximum PCE and TCE soil gas levels in the FVN were 3,200 and 4,300 ug/m^3, respectively, with TCA as high as 2,000 ug/m^3. All three FVN maximum detections were found at soil gas station FV-22 (Figure 2). The results of the soil gas sampling in the FVN, however, may underestimate chemical concentrations under buildings where contaminants tend to pool and concentrate.

DOH estimated levels of VOCs that might be present in indoor air in the FVN using the soil gas and groundwater data collected by Cadet and the revised Johnson and Ettinger (1991) model for subsurface vapor intrusion into buildings.[6] The J&E models were designed to predict the incremental carcinogenic risk and non-carcinogenic hazard quotients associated with site specific soil gas and groundwater contaminant concentrations. The models, however, tend to underestimate the carcinogenic risks and non-carcinogenic hazard quotients associated with chlorinated solvents like those detected at the Cadet site.[6]

Two building scenarios are available in the model: buildings underlain by a basement or buildings underlain by a slab-on-grade. Because soil gas sampling results were only obtained from 3 to 4 feet below the ground surface in the FVN, only the slab-on-grade scenario was modeled. The slab-on-grade scenario was also used to predict the indoor air concentrations and associated health risks associated with the groundwater to indoor air pathway. Because of these limitations the carcinogenic risks and non-carcinogenic hazard quotients obtained during the modeling may be underestimated for buildings with basements.

Appendix D describes input parameters used during the modeling and the modeling results. VOC concentrations detected in soil gas and groundwater in the FVN are shown in Tables D1 and D3. The estimated potential indoor air risks associated with maximum VOC concentrations found in soil gas and groundwater in the FVN are given in Tables D2 and D4.

Although production wells at Great Western Malting are not used for drinking, a potential indoor air inhalation pathway was considered prior to March 2001, before the installation of air stripping towers. Passage of groundwater through the air-washing system, agitation and heating of this water used during steeping and germination, and heating of damp grain during kiln-drying could have released TCE in process water to indoor air.[7] Despite low levels of TCE in process water, this pathway was considered because of the very large amounts of water used in processing. An average concentration of 10.2 and 10.5 ug/L TCE was detected in wells 4 and 5, respectively, during quarterly sampling between January 1998 and April 2000. Based on the amount of TCE entering the facility and available for off-gassing, a maximum concentration of 13.8 ug/m^3 TCE was estimated in indoor air.[7] This concentration does not exceed EPA's health comparison value of 40 ug/m^3. This modeled concentration of TCE in indoor air was also evaluated for potential cancer risk of workers. The estimated cancer risk calculated for this exposure is not considered to be significant. Because wells 4 and 5 are now treated, potential health risk are even further reduced and, therefore, this pathway is not a health concern.

Discussion

Environmental sampling data were screened using federal ATSDR and U.S. Environmental Protection Agency (EPA), health-based criteria (comparison values). Contaminant concentrations below comparison values are unlikely to pose a health threat, and were not further evaluated in this health consultation. Contaminant concentrations exceeding comparison values do not necessarily pose a health threat, but were further evaluated to determine whether they are at levels which could result in adverse human health effects.

There are two completed pathways of exposure associated with the Cadet site. They are inhalation of contaminated indoor air at the Cadet facility and inhalation of contaminated indoor air in FVN homes. There are two additional completed pathways from VOCs in private drinking water wells north of Cadet, and contaminated drinking water from Port of Vancouver wells, however, there does not appear to be evidence linking these targets to Cadet.

Volatile Organic Compounds in Private Drinking Water Wells

Each of the chemicals detected in private drinking water wells northwest of Cadet that exceeded their respective health comparison values were evaluated for both cancer and non-cancer health effects (Table B2). It is useful to note that the maximum levels of TCE and PCE found in these private wells do not exceed drinking water standards, known as maximum contaminant levels (MCLs), enforced for public water systems.

Exposure doses given below are based on the maximum concentrations detected and so represent a "worst case scenario." The ingested dose from drinking water was doubled in order to take into account skin absorption and inhalation of vapors resulting from showering, bathing and other indoor water uses. The assumption is that the combined dose from these two routes of exposure is equivalent to that of ingestion.[9,10] It should be recognized that use of the maximum contaminant concentration may result in an over-estimation of actual exposure. Exposure dose calculations for contaminants exceeding comparison values are provided in Appendix C.

Non-cancer effects

In order to evaluate possible non-cancer effects from exposure to contaminated drinking water, an exposure dose was calculated and then compared to EPA's Oral Reference Dose (RfD). An oral reference dose (RfD) is a level of exposure to chemicals below which non-cancerous effects are not expected. RfDs are based on toxicity observed in animal or human studies involving exposure to the chemical of concern. In order to account for uncertainties in toxicity data and provide adequate health protection, RfDs are set below toxic effect levels with the use of "safety factors."

Oral Reference Dose (RfD)

An oral reference dose (RfD) is a level of exposure to chemicals below which non-cancerous effects are not expected. RfDs are set by the Environmental Protection Agency (EPA).

An estimated exposure dose that exceeds the RfD indicates only the potential for adverse health effects. The degree to which the RfD is exceeded by the exposure dose indicates how close it will be to the actual toxic effect level. If the estimated exposure dose is only slightly above the RfD, then that dose will fall well below the toxic effect level. The higher the estimated dose is above the RfD, the closer it will be to the toxic effect level.

The estimated doses for a child drinking 1 liter of water per day at the maximum concentrations of TCE (4.37 ppb) and PCE (1.13) are given in Appendix C, Table C1. The dose estimated for TCE is approximately two times higher than its proposed RfD while the dose estimated for PCE is well below its respective RfD. The RfD for TCE is based on liver, kidney and developmental toxicity observed in rats and mice. These effects are considered to be the most sensitive endpoints of TCE toxicity. Although the estimated dose for TCE is sightly higher than the proposed RfD, it is 2,000 times below the actual toxic effect level upon which the RfD is based and, therefore, is not expected to cause non-cancerous health effects.

Cancer effects

Recent and extensive review of available data has led EPA to characterize TCE as "highly likely to produce cancer in humans." EPA's former classification of PCE as a probable human carcinogen is currently under review; however, other health agencies consider PCE to be a probable human carcinogen. These classifications are based on sufficient evidence in animals and limited evidence in humans. However, the potential of TCE and PCE to cause cancer at the low-levels of exposure found at the Cadet site is not clear. The strongest evidence that TCE can cause cancer in humans comes from occupational studies that have found increases in lung, liver and kidney cancers in workers exposed over several years. The levels of exposure in these studies are generally much higher than those estimated for the Cadet site while exposure doses used in animal studies are thousands of times higher.

Although the data obtained from high-dose animal or worker exposure studies is not directly applicable to exposures found at Cadet, theoretical cancer risk estimates can be made based on this data. Such estimates are made with mathematical equations that use this high-dose data to predict how many cancers might occur at lower doses. This process involves much uncertainty. Current thinking suggests that there is no "safe dose" of a carcinogen and that a very small dose of a carcinogen will give a very small cancer risk. Cancer risk estimates are, therefore, not *yes/no* answers but measures of chance (probability). Such measures, however uncertain, are useful in determining the magnitude of a cancer threat since any level of a carcinogenic contaminant carries an associated risk. The validity of the "no safe dose" assumption for cancer-causing chemicals is not clear. Some evidence suggests that certain chemicals considered to be carcinogenic must exceed a threshold of tolerance before initiating cancer.

Cancer risk estimated from long-term exposure to the maximum levels of PCE and TCE found in drinking water near the Cadet site are given in Table C2. Since the source of VOCs has been present for more than 30 years, doses were calculated assuming a 30-year exposure of a child growing to adulthood averaged over a lifetime of 70 years. These estimates indicate only a very low risk for cancer.

Cancer Risk

Cancer risk estimates do not reach zero no matter how low the level of exposure to a carcinogen. Terms used to describe this risk are defined below as the number of excess cancers expected in a lifetime:

Term		# of Excess Cancers
moderate	is approximately equal to	1 in 1,000
low	is approximately equal to	1 in 10,000
very low	is approximately equal to	1 in 100,000
slight	is approximately equal to	1 in 1,000,000
insignificant	is less than	1 in 1,000,000

Port of Vancouver Drinking Water Wells

The three Port of Vancouver drinking water wells are located approximately one mile south-southeast from the former Swan Manufacturing site, and 1.25 miles along the groundwater route (one-half mile east then 3/4 of a mile south). These wells provide drinking water service to approximately 40 percent of the Port industrial area. Maximum levels of TCE and PCE found in Port wells, to date, are 6.7 ppb (March 1996) and 0.7 ppb (March 1998), respectively. No contaminants have been detected since March 1998. The MCL for both TCE and PCE is 5 ppb.

Infrequent detections and the lack of significant inhalation exposure (i.e., limited showering or other household uses that release VOCs into indoor air) indicate that exposures from Port wells are probably lower than what is estimated above for private wells.

Maximum Contaminant Level (MCL)

The MCL is a regulatory limit set by the Environmental Protection Agency (EPA) for contaminants in public drinking water. If an MCL is exceeded, regulatory action is required under the Safe Drinking Water Act. MCLs are not always strictly health based but can consider technological or economic feasibility. The Washington State Department of Health (DOH) regulates public drinking water supplies in Washington State.

Volatile Organic Compounds in Indoor Air at Cadet

The maximum indoor air concentrations of TCE, PCE, 1,4 dichlorobenzene, and m,p-xylene measured at the Cadet facility were all well below OSHA's permissible exposure limits (PEL) (Table B3). PEL's are enforceable regulatory limits on the amount or concentration of a substance in workplace air. However, workplace health comparison values are often several orders of magnitude higher than those set for the general public. The level of TCE measured in indoor air at Cadet (110 ug/m^3) exceeds the inhalation reference concentration (RfC) of 40 $\mu g/m^3$ set by EPA. The RfC is a contaminant level in air below which non-carcinogenic health effects are not expected. RfCs are set for the general public as opposed to the workplace. The measured level of TCE is also well-above what is considered to be a background level in indoor air. The very high concentrations of TCE and PCE found in groundwater beneath and near the Cadet facility indicate that TCE and PCE could be moving inside from groundwater (Table B1).

The RfC for TCE is based on critical effects in the central nervous system, liver, and endocrine system.[9] Since the RfC assumes a continuous exposure (24-hours a day, 7-days-per-week), it is not appropriate for comparison with workplace exposures. Therefore, the RfC was adjusted to 175 $\mu g/m^3$ to account for the fact that most people work eight hours per day and five days per week with two weeks vacation. Based on the adjusted RfC, *it is not likely that workers at Cadet will experience adverse, non-carcinogenic health effects from inhalation of TCE.*

Background

Background is defined here as the amount of TCE expected to be present in air without any known contribution from a particular source. Since VOCs are expected to be present in urban indoor and outdoor air, it is useful to estimate what the expected level is in order to determine whether levels are higher due to an identified source.

Cancer risks associated with exposure to TCE and PCE in workplace air are shown in Table C3. The levels of TCE and PCE measured in indoor air at Cadet indicates a *low to moderate cancer risk*. As noted previously, EPA is currently reviewing the carcinogenic potential of TCE and PCE. The cancer potency factors (also known slope factors) used to calculate risk are also under review and, therefore, the risk

estimates provided here must be viewed with caution. Further, these estimates are based on a single sampling round that may not be representative of actual exposures.

Volatile Organic Compounds in Indoor Air in the Fruit Valley Neighborhood

Based on the vapor intrusion modeling, contaminated groundwater appears to pose a low health risk for the indoor air pathway in the FVN. Appendix D, Table 2 shows the incremental risk and hazard quotients from the maximum concentrations of five contaminants detected in soil vapor for three different types of soil (sand, loamy sand, and sandy loam). Appendix D, Table 4 shows the non-carcinogenic hazard quotient and the incremental carcinogenic risk from groundwater beneath FVN.[6,8] The modeling results, however, may not accurately reflect actual conditions in FVN. As stated earlier, the soil gas samples were collected away from buildings where contaminants tend to pool and concentrate, only the slab-on-grade building scenario was evaluated, and the J&E model tends to underestimate the carcinogenic risk and non-carcinogenic hazard quotient associated with chlorinated solvents such as TCE and PCE. As a result, the risk may be underestimated.

Multiple Chemical Exposure

In almost every situation of environmental exposure, there are multiple contaminants to consider. The potential exists for these chemicals to interact in the body and increase or decrease the potential for adverse health effects. The vast number of chemicals in the environment make it impossible to measure all of the possible interactions between these chemicals. Individual cancer risk estimates can be *added* since they are measures of probability. When estimating non-cancer risk, however, similarities must exist between the chemicals if the doses are to be added. Groups of chemicals that have similar toxic effects can be added such as TCE, PCE, 1,4-dichlorobenzene and m,p-xylene, which cause liver toxicity. Although some chemicals can interact to cause a toxic effect that is *greater than* the added effect, there is little evidence demonstrating this at concentrations commonly found in the environment.

The combined exposures for residents and workers exposed to VOCs near the Cadet site is not expected to substantially increase the health risk that are evaluated above for each individual contaminant. The exposures estimated for TCE are the most significant of the contaminants found based on concentration and toxicity data.

Exposure Pathways and Children

ATSDR's Child Health Initiative recognizes that the unique vulnerabilities of infants and children deserve special emphasis with regard to exposures to environmental contaminants. Infants, young children, and the unborn may be at greater risk than adults from exposure to particular contaminants. Exposure during key periods of growth and development may lead to

malformation of organs (teratogenesis), disruption of function, and even premature death. In certain instances, maternal exposure, via the placenta, could adversely effect the unborn child.

After birth, children may receive greater exposures to environmental contaminants than adults. Children are often more likely to be exposed to contaminants from playing outdoors, ingesting food that has come into contact with hazardous substances, or breathing soil and dust. Pound for pound body weight, children drink more water, eat more food, and breathe more air than adults. For example, in the United States, children in the first 6 months of life drink 7 times as much water per pound as the average adult. The implication for environmental health is that, by virtue of children's lower body weight, given the same exposures, they can receive significantly higher relative contaminant doses than adults.

The exposures discussed above considered the increased exposure of young children compared to adults. Even under "worst-case" assumptions of exposure to the maximum levels of VOCs detected in drinking water, health risks for children are considered unlikely.

Conclusions

1. Computer modeling predicts only a low potential health risk from volatile organic compounds (VOCs) migrating into indoor air from groundwater. However, the risks may be underestimated because of data and model limitations. Therefore, potential exposure to VOCs in indoor air in FVN homes represents an *indeterminate public health hazard*.

2. No *apparent public health hazard* exists from exposure to maximum concentrations of TCE and PCE in drinking water in the two private wells north of Cadet. Levels of TCE and PCE in these wells are not likely to result in any adverse health effects. However, this exposure would be of concern should levels of TCE or PCE increase. Exposure to TCE and PCE should be eliminated when these two residences are connected to the municipal water supply.

3. No *apparent public health hazard* exists from exposure to maximum concentrations of TCE and PCE in drinking water from the three Port of Vancouver wells located south of Cadet. Detections have been infrequent in the past and no VOCs have been found since 1998. Exposure to TCE and PCE will be eliminated when the Port connects to the municipal water supply.

4. Indoor air concentrations of TCE, PCE, 1,4-dichlorobenzene, and mixed xylenes at the Cadet facility appear to be elevated. The level of TCE measured is particularly high although it is well below workplace standards. However, the single sampling round conducted in March 2001 is not sufficient to determine actual exposure of workers to indoor air levels of VOCs. Therefore, *exposure of workers to VOCs in indoor air at Cadet represent an indeterminate health hazard.*

5. No *apparent public health hazard* exists from exposure to TCE in wells supplying process water for Great Western Malting. These wells are not used for drinking and the estimated indoor air levels that might result from off-gassing inside the facility are below

a level of health concern.

Recommendations/Public Health Action Plan

6. DOH recommends indoor air sampling inside residential homes and crawl spaces in the Fruit Valley Neighborhood.

   - ♦ DOH is available to assist with the development and review of an indoor air sampling plan. Results of indoor samples should be sent to the DOH for evaluation.

   - ♦ Future soil gas samples in the Fruit Valley Neighborhood should be collected under slabs or floors of structures that are considered to be at risk. When this cannot be accomplished, enough samples should be collected adjacent to these structures so that a good estimate of average concentration can be made.

   - ♦ The Johnson & Ettinger vapor intrusion model contains useful guidance for soil gas sampling that should be consulted when developing a sampling plan.

2. Continued sampling of indoor air for VOCs is necessary to better estimate exposure of workers at the Cadet facility. While VOC levels in indoor air at Cadet do not exceed workplace standards, levels do exceed what is considered to be background for a typical indoor air environment. High concentrations of VOCs in groundwater near Cadet may be a source.

References

1. Interim Action source Investigation Work Plan, Cadet Manufacturing Site, AGRA Earth & Environmental, Inc. March 2000.

2. Memo from C. Rankine to S. Matthews, Rufener Property Groundwater Sampling. July 23, 2001.

3. Washington State Department of Ecology. Summary Score Sheet. Cadet Manufacturing Company, Site Hazardous Assessment #99-01.

4. Semi-Annual Groundwater Monitoring Report 2001, Cadet Manufacturing Company, AMEC. November 13, 2001.

5. Letter to C. Rankine, Ecology, from B. Lary, AMEC Earth & Environmental, Inc. Additional Source Investigation, Cadet Manufacturing Company. February13, 2001.

6. User's Guide for the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings (Revised), Environmental Quality Management, Inc., for US EPA Office of Emergency and Remedial Response. December 2000.

7. Letter to J. Hamachek, Great Western Malting, from Maul Foster & Alongi, Inc. June 23, 2000.

8. Cadet Manufacturing, Johnson & Ettinger Soil Gas and Groundwater Screening Model Summary, B. Trejo. October 17, 2001.

9. US Environmental Protection Agency. Trichloroethylene Health Risk Assessment: Synthesis and Characterization (External Review Draft). August 1, 2001.

10. Agency for Toxic Substances and Disease Registry. Public Health Assessment Guidance Manual, Lewis Publishers, Chelsea, Michigan, 1992.

11. McKone, TE. Household exposure models. *Toxicology Letters.* 1989; 49:321-39.

Appendix A: Figures

Figure 1. Site location map for Cadet Manufacturing Company, Vancouver, Washington (adapted from Ref. 1).

Figure 2 hard copy inserted here

Appendix B: Tables

Table B1. Volatile organic compounds in groundwater at the Cadet Manufacturing Company located in Vancouver, WA (ppb)

Contaminant	Groundwater Concentration	Location of Sample (Figure 2)	Comparison Value	Cancer Class	Comparison Value Reference
TCE	78,000	C-13	3	EPA-UR IARC-3 NTP-2	CREG
PCE	70,000	C-9	0.7	EPA-UR IARC-2A NTP-2	
1,1,1-TCA	6,290	DPW-1	200	NTP-3	MCL
cis-1,2-DCE	1,600	C-13	70		
1,1-DCE	10.8	DPW-06	7	EPA-C NTP-3	

EPA-UR = Under review - U.S. Environmental Protection Agency
IARC-3 = Not classifiable - International Agency for Research on Cancer
NTP-2 = Reasonably anticipated to be a carcinogen - National Toxicology Program - National Institute for Environmental Health Sciences
NTP-3 = Not classified
IARC-2A = Probably carcinogenic to humans (limited human evidence; sufficient evidence in animals)
EPA-C = Possible human carcinogen (no human, limited animal studies)

Table B2. Volatile organic compounds in residential drinking water northwest of the Cadet Manufacturing Company located in Vancouver, WA (ppb)

Contaminant	Sampling Date	Primary Residence (Farm)	Rental House	Comparison Value	Cancer Class	Comparison Value Reference
TCE	September 1998	ND	3.99	3	EPA-UR IARC-3 NTP-2	CREG
	July 2001	0.51	4.37			
PCE	September 1998	ND	ND	0.7	EPA-UR IARC-2A NTP-2	
	July 2001	1.13	0.65			

ND = Not detected
EPA-UR = Under review - U.S. Environmental Protection Agency
IARC-3 = Not classifiable - International Agency for Research on Cancer
NTP-2 = Reasonably anticipated to be a carcinogen - National Toxicology Program - National Institute for Environmental Health Sciences
IARC-2A = Probably carcinogenic to humans (limited human evidence; sufficient evidence in animals)

Table B3. Indoor air sampling results at the Cadet Manufacturing Company located in

Vancouver, WA (ug/m^3)

Contaminant	Air Concentration	Permissible Exposure Limit (PEL)	Minimal Risk Level (MRL)	Reference Concentration (RfC)	Cancer Class
TCE	110	270,000	537 [a]	40 [b]	EPA-UR IARC-3 NTP-2
PCE	35	678,000	271	NA	EPA-UR IARC-2A NTP-2
1,4-dichlorobenzene	98	450,000	601	800	IARC-2B NTP-2
m,p-xylene	28	435,000	434	NA	NTP-3

a : Based on exposure < 365 days
b: RfC needs to be corrected (raised) in order to account for the reduced exposure duration and frequency of a worker versus residential scenario. The corrected value given in the Discussion is 175 ug/m^3 based on a 8 hours/day, 5 days/week, 50 weeks/year schedule.
NA: Not available
EPA-UR: Under review - U.S. Environmental Protection Agency
IARC-3: Not classifiable - International Agency for Research on Cancer
NTP-3: Not classified - National Toxicology Program - National Institute for Environmental Health Sciences
IARC-2A: Probably carcinogenic to humans (limited human evidence; sufficient evidence in animals)
NTP-2: Reasonably anticipated to be a carcinogen
EPA-C: Possible human carcinogen (no human, limited animal studies)

Appendix C: Exposure Dose Calculations

This section provides the calculated exposure doses and assumptions used for each completed exposure pathway. The dose estimates for each of these pathways are described in the discussion section of the document. Maximum concentrations are used to calculate these doses, representing a "worst-case" scenario that may overestimate actual exposure.

Dose estimates for residents living in the two homes north of Cadet exposed to TCE and PCE in drinking water include skin absorption and inhalation of vapors resulting from showering, bathing and other indoor water uses. The assumption is that the combined dose from these two routes of exposure is equivalent to that of ingestion. This assumption is supported by ATSDR guidance although some mathematical models indicate that the inhaled dose for VOCs volatilizing from drinking water can be several times higher than the ingested dose. The following exposure dose equation and exposure assumptions were used to calculate the doses given below in Tables C1 and C2.

Ingested Dose - Drinking Water

Non-cancer

$$ID_{0\text{-}5} = \frac{C_{dw} \times IR_{0\text{-}5} \times CF \times EF_{0\text{-}5} \times ED}{BW_{0\text{-}5} \times AT_{non\text{-}cancer}}$$

Cancer

$$\sum (ID_{0\text{-}5,6\text{-}15,16\text{-}30} \times CSF)$$

$$ID_{0\text{-}5} = \frac{C_{dw} \times IR_{0\text{-}5} \times CF \times EF_{0\text{-}5} \times ED}{BW_{0\text{-}5} \times AT_{cancer}}$$

$$ID_{6\text{-}15} = \frac{C_{dw} \times IR_{6\text{-}15} \times CF \times EF_{6\text{-}15} \times ED}{BW_{6\text{-}15} \times AT_{cancer}}$$

$$ID_{16\text{-}30} = \frac{C_{dw} \times IR_{16\text{-}30} \times CF \times EF_{16\text{-}30} \times ED}{BW_{16\text{-}30} \times AT_{cancer}}$$

Ingestion Exposure Assumptions

ID = Ingested Dose (mg/kg-day)
C_{dw} = Concentration in drinking water (ug/l)
$IR_{0\text{-}5}$ = Ingestion Rate = 0.9 l/day
$IR_{6\text{-}15}$ = Ingestion Rate = 1.0 l/day
$IR_{16\text{-}30}$ = Ingestion Rate = 1.4 l/day
CF = Conversion Factor = 0.001 mg/ug
EF = Exposure Frequency = 350 days/year
$ED_{0\text{-}5}$ = Exposure Duration = 5 years
$ED_{6\text{-}15}$ = Exposure Duration = 10 years
$ED_{16\text{-}30}$ = Exposure Duration = 15 years
$BW_{0\text{-}5}$ = Body Weight = 15 kg
$BW_{6\text{-}15}$ = Body Weight = 41 kg
$BW_{16\text{-}30}$ = Body Weight = 72 kg
$AT_{non\text{-}cance\ r}$ = Averaging Time = 1825 days
AT_{cancer} = Averaging Time = 25550 days

Inhaled Dose - Workers

Non-cancer

$$IhD = \frac{C_{air} \times Inh \times CF \times EF \times ED}{BW \times AT_{non\text{-}cancer}}$$

Cancer

$$IhD = \frac{C_{air} \times Inh \times CF \times EF \times ED}{BW \times AT_{cancer}}$$

Inhalation Exposure Assumptions

IhD = Inhaled Dose (mg/kg-day)
C_{air} = Concentration in air (ug/m^3)
Inh = Inhalation Rate = 10.4 m^3/day
CF = Conversion Factor = 0.001 mg/ug
EF = Exposure Frequency = 250 days/year
ED = Exposure Duration = 25 years
BW = Body Weight = 72 kg
$AT_{non\text{-}cance\ r}$ = Averaging Time = 9125 days
AT_{cancer} = Averaging Time = 25550 days

Table C1. Non-cancer dose calculations for a child drinking water from residential wells near the Cadet Manufacturing Company in

Vancouver, WA [a]

Receptor Population	Exposure Route	Contaminant	Maximum Concentration (ppb)	Estimated Dose (mg/kg-day)	RfD (mg/kg/day)	LOAEL (mg/kg/day)
Child (0-5years)	Ingestion Inhalation Dermal	TCE	4.37	5E-4	3E-4	1.0
		PCE	1.13	1E-4	1E-2	100 [b]

a = The maximum ingested dose from drinking water was doubled in order to take into account inhalation and dermal absorption from other sources of exposure such as showering, dish washing, etc.
b = The RfD for PCE is actually based on a no-observed adverse effect level (NOAEL) of 14 mg/kg/day.

Table C2. Cancer risk calculations for drinking water exposure in residential wells near the Cadet Manufacturing Company in Vancouver, WA [a]

Receptor Population	Exposure Route	Contaminant	Maximum Concentration (ppb)	Cancer Slope Factor [b] (per mg/kg-day^{-})	Cancer Risk
Child > Adult (30 yeas)	Ingestion Inhalation Dermal	TCE	4.37	0.4	4E-5
				0.02	2E-6
		PCE	1.13	0.052	1E-6

a = The maximum ingested dose from drinking water was doubled in order to take into account inhalation and dermal absorption from other sources of exposure such as showering, dish washing, etc.
b = TCE cancer risk calculations are made using either end of the suggested range of cancer slope factors provided by EPA in their draft health assessment for TCE. The lower of the two is based on an inhalation exposure of workers while the higher is derived from a residential drinking water study.

Table C3. Cancer risk calculations for indoor air exposure of workers at the Cadet Manufacturing Company in Vancouver, WA

Receptor Population	Exposure Route	Contaminant	Maximum Concentration (ug/m^3)	Cancer Slope Factor [a] (per mg/kg/day)	Cancer Risk
Workers	Inhalation	TCE	110	0.4	1E-3
				0.02	7E-5
		PCE	35	0.002	2E-6
		1,4-dichlorobenzene	98	NA	NA
		m,p-xylene	28	NA	NA

a = TCE cancer risk calculations are made using either end of the suggested range of cancer slope factors provided by EPA in their draft health assessment for TCE. The lower of the two is based on an inhalation exposure of workers while the higher is derived from a residential drinking water study.

Appendix D. Johnson & Ettinger Soil Gas and Groundwater Screening Model (First Tier) Summary for Cadet Manufacturing

The J&E models were designed to evaluate whether buildings underlain by a basement (200 cm) or slab-on-grade (15 cm) would be affected by vapors migrating into indoor air from contaminated soil gas and groundwater. Because of limitations associated with the depth of the soil gas sampling (3-4 feet) in the FVN, only the slab-on-grade scenario was evaluated during the soil gas modeling. The same building scenario was used when modeling the groundwater to indoor air pathway. Because only limited modeling was conducted, the carcinogenic risks and non-carcinogenic hazard quotients obtained may be over or underestimated.

Soil Gas

Cadet collected and analyzed soil gas samples from three to four feet below ground surface (bgs) in the FVN to estimate chlorinated solvent concentrations. The soil gas samples were collected using a push probe technique. Table D1 summarizes the range of chemical concentrations detected in soil gas.

Table D1. Soil gas chemical concentrations in the Fruit Valley neighborhood near the Cadet Manufacturing Company located in Vancouver, WA (ug/m^3)

Chemical	CAS No.	Min. Conc.	Max. Conc.
1,1-dichloroethene	75354	<1	<200
cis 1,2-dichloroethene	156592	<1	<200
1,1,1-trichloroethane	71556	<2	2000
trichloroethene	79016	<2	4300
tetrachloroethene	127184	16	3200

The J&E soil gas screening model was used to evaluate whether the maximum concentration of chlorinated solvent soil gas concentrations detected poses a health risk to people in the nearby FVN. The model predicts steady-state indoor air chemical concentrations and incremental risk and/or hazard quotients associated with the soil gas concentration data.

The model operates under the assumption that the soil column properties are homogeneous and isotropic. Since this rarely occurs in nature, the model was run using three different soil types (sand [S], loamy sand [LS], and sandy loam [SL]). These soil types were selected based on limited soil information available for the site. The groundwater temperature used for the modeling (12º C for western Washington) was extrapolated from average U.S. shallow groundwater temperature data provided in the J&E guidance document.

Default values were used for vadose zone soil properties – soil dry bulk density, soil total porosity, and soil water filled porosity. Default values were also used for averaging time for carcinogens, averaging time for non-carcinogens, exposure duration, and exposure frequency when calculating the incremental risks. The unit risk factor (URF) or reference concentration

(RfC) provided in the J&E model for 1,1 dichloroethene, cis 1,2-dichloroethene, tetrachloroethene, and 1,1,1-trichloroethane were used during the modeling. A URF was calculated for TCE based on the proposed U.S. EPA cancer slope factor of 0.02 kg-day/mg. This slope factor is based on a worker inhalation exposure.

Table D2 summarizes the potential indoor air risk results associated with the maximum concentration of each chemical in the soil gas. The incremental risks associated with the modeled indoor air concentrations of individual chemicals from soil gas ranged from 2.4E-08 to 8.1E-07. The hazard quotients ranged from 4.2E-04 to 6.3E-05.

Table D2. Indoor air cancer risks and hazard quotients estimated from soil gas levels for the Fruit Valley neighborhood located near the Cadet Manufacturing, Vancouver, WA

Chemical	Concentration (ug/m^3)	Vadose Zone Soil Type*	Cancer Risk	Hazard Quotient
1,1-dichloroethylene	200	S	3.60E-07	NA
		LS	2.30E-07	
		SL	1.40E-07	
cis 1,2-dichloroethene	200	S	NA	4.20E-04
		LS		2.80E-04
		SL		1.80E-04
1,1,1-trichloroethane	2000	S	NA	1.50E-04
		LS		1.00E-04
		SL		6.30E-05
trichloroethylene	4300	S	8.10E-07	NA
		LS	5.40E-07	
		SL	3.30E-07	
tetrachloroethylene	3200	S	5.70E-08	NA
		LS	3.90E-08	
		SL	2.40E-08	

* S = Sand; LS = Loamy Sand; SL = Sandy Loam

Groundwater

The J&E groundwater screening model was also run to evaluate the groundwater to indoor air pathway using the slab-on-grade building scenario. Groundwater data obtained from the August 2001 sampling round was used to predict the incremental risk and/or hazard quotient associated with the same chlorinated solvents evaluated during the soil gas modeling. The maximum groundwater concentration of each of the five chemicals that were detected during the soil gas monitoring was selected for the modeling. Table D3 summarizes the groundwater data used during the modeling.

Table D3. Groundwater chemical concentrations in the Fruit Valley neighborhood near Cadet Manufacturing located in Vancouver, WA (ppb)

Chemical	CAS No.	Monitoring Well No.	Max. Conc.
1, 1 - dichloroethene	75354	MW-03S	5.3
cis 1, 2 - dichloroethene	156592	MW-06S	8.55
1, 1, 1 - trichloroethane	71556	MW-06S	49.2
trichloroethylene	79016	MW-05S	1420
tetrachloroethylene	127184	MW-05S	169

Based on information provided by Cadet, shallow groundwater depth in the vicinity of the site varies seasonally with precipitation. Groundwater depth is shallowest in the spring, approximately 8 feet bgs. The deepest groundwater depths occur in the fall, approximately 21 feet bgs. The groundwater-screening model was run using both depths. For modeling purposes, it was assumed that the August 2001 results represented groundwater concentrations that would be detected throughout the year. Consistent with the soil gas modeling, an estimated groundwater temperature of 12ºC was used.

The groundwater screening model, like the soil gas model, was run using three different soil types (sand [S], loamy sand [LS], and sandy loam [SL]). Default values were used for vadose zone soil properties – soil dry bulk density, soil total porosity, and soil water filled porosity. Default values were also used for averaging time for carcinogens, averaging time for non-carcinogens, exposure duration, and exposure frequency when calculating the incremental risks. The unit risk factor (URF) or reference concentration (RfC) provided in the J&E model for 1,1 dichloroethene, cis 1,2-dichloroethene, tetrachloroethene, and 1,1,1-trichloroethane were used during the modeling. A URF was calculated for TCE based on the proposed U.S. EPA cancer slope factor of 0.02 kg-day/mg. This slope factor is based on a worker inhalation exposure.

Table D4 summarizes the potential indoor air risk results associated with the maximum concentration of each chemical in the shallow groundwater associated with the slab-on-grade building scenario. The incremental risks associated with the modeled indoor air concentrations of individual chemicals from groundwater ranged from 2.5E-05 to 1.4E-07. The hazard quotients ranged from 7.0E-04 to 1.8E-04.

Table D4. Indoor air cancer risks and hazard quotients estimated from groundwater levels for the Fruit Valley neighborhood located near Cadet Manufacturing, Vancouver, WA

Chemical	GW Conc (ug/l)	SCS Soil Type*		GW Depth (ft(cm) bgs)	Indoor Air	
		Above Water Table	Vadose Zone		Cancer Risk	Hazard Quotient (Non Cancer)
1,1 - dichloroethene	5.3	S	S	8(244)	2.7E-06	NA
		S	S	21(640)	1.0E-06	
		LS	LS	8(244)	2.1E-06	
		LS	LS	21(640)	9.4E-07	
		SL	SL	8(244)	1.5E-06	
		SL	SL	21(640)	8.0E-07	
cis 1,2 - dichloroethene	8.55	S	S	8(244)	NA	7.00E-04
		S	S	21(640)		2.70E-04
		LS	LS	8(244)		5.60E-04
		LS	LS	21(640)		2.40E-04
		SL	SL	8(244)		4.20E-04
		SL	SL	21(640)		2.10E-04
1,1,1 - trichloroethane	49.2	S	S	8(244)	NA	6.10E-04
		S	S	21(640)		2.30E-04
		LS	LS	8(244)		4.90E-04
		LS	LS	21(640)		2.10E-04
		SL	SL	8(244)		3.60E-04
		SL	SL	21(640)		1.80E-04
trichloroethylene	1420	S	S	8(244)	2.5E-05	NA
		S	S	21(640)	9.4E-06	
		LS	LS	8(244)	2.0E-05	
		LS	LS	21(640)	8.6E-06	
		SL	SL	8(244)	1.5E-05	
		SL	SL	21(640)	7.4E-06	
tetrachloroethylene	169	S	S	8(244)	4.6E-07	NA
		S	S	21(640)	1.7E-07	
		LS	LS	8(244)	3.7E-07	
		LS	LS	21(640)	1.6E-07	
		SL	SL	8(244)	2.8E-07	
		SL	SL	21(640)	1.4E-07	

* S = Sand; LS = Loamy Sand; SL = Sandy Loam

Preparer of Report

Steve Matthews
Office of Environmental Health Assessments
Washington State Department of Health

Certification

This Health Consultation was prepared by the Washington State Department of Health under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the health consultation was begun.

____

Debra Gable
Technical Project Officer, SPS, SSAB, DHAC
ATSDR

The Division of Health Assessment and Consultation, ATSDR, has reviewed this public health consultation and concurs with the findings.

____

Richard Gillig
Chief, SPS, SSAB, DHAC
ATSDR